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## *Revisiting afro-alpine Lake Garba Guracha in the Bale Mountains of Ethiopia*

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# Revisiting afro-alpine Lake Garba Guracha in the Bale Mountains of Ethiopia - rationale, chronology, geochemistry, and paleoenvironmental implications

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## -Supplementary Data-

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Table S1. Chronology BAL-GGU17-AB. Uncertainties of $^{14}C$ ages refer to 68% probabilities (1σ), whereas ranges of calendar ages represent 95% probabilities (2σ). $^{14}C$ ages were calibarated with IntCal13

| Lab. Name | Dating lab code | IPE-CSIC/ UH code | Dating method | Depth (cm) | $^{14}C$ age (BP) | Uncertainty (yr) | Calendar ages (cal BP) |
|---|---|---|---|---|---|---|---|
| ECRC-UCL | BAL0 | BAL0 | $^{210}Pb$-$^{137}Cs$ | 0 | | 1 | -67 |
| | BAL1.5 | BAL1.5 | | 1.5 | | 2 | -64 |
| | BAL4.5 | BAL4.5 | | 4.5 | | 2 | -47 |
| | BAL6.5 | BAL6.5 | | 6 | | 3 | -26 |
| | BAL7.5 | BAL7.5 | | 7 | | 5 | -13 |
| | BAL8.5 | BAL8.5 | | 8 | | 5 | -10 |
| | BAL9.5 | BAL9.5 | | 9 | | 5 | -8 |
| | BAL10.5 | BAL10.5 | | 10 | | 5 | -6 |
| | BAL12.5 | BAL12.5 | | 12 | | 5 | -1 |
| | BAL14.5 | BAL14.5 | | 14 | | 5 | 4 |
| | BAL16.5 | BAL16.5 | | 16 | | 6 | 8 |
| | BAL18.5 | BAL18.5 | | 18 | | 6 | 13 |
| | BAL20.5 | BAL20.5 | | 20 | | 6 | 17 |
| | BAL22.5 | BAL22.5 | | 22 | | 7 | 21 |
| | BAL24.5 | BAL24.5 | | 24 | | 7 | 26 |
| | BAL26.5 | BAL26.5 | | 26 | | 8 | 31 |
| | BAL28.5 | BAL28.5 | | 28 | | 9 | 34 |
| | BAL31.5 | BAL31.5 | | 31 | | 10 | 40 |
| | BAL34.5 | BAL34.5 | | 34 | | 11 | 46 |
| | BAL38.5 | BAL38.5 | | 38 | | 13 | 56 |
| | BAL42.5 | BAL42.5 | | 42 | | 14 | 68 |
| | BAL46.5 | BAL46.5 | | 46 | | 15 | 78 |
| | BAL51.5 | BAL51.5 | | 51 | | 18 | 94 |
| LARA Bern | BE-7931.1.1 | GG1B1 | $^{14}C$-Bulk Sediment | 105 | 935 | 118 | 662-1081 |
| | BE-8273.1.1 | GG1B1A | $^{14}C$-n-alkane | 105 | 1076 | 79 | 892-1180 |
| | BE-8282.1.1 | 2L15.16 | $^{14}C$-Charcoal | 185 | 2124 | 129 | 1779-2366 |
| | BE-7930.1.1 | GG1B2 | $^{14}C$-Bulk Sediment | 205 | 2323 | 111 | 2110-2722 |
| | BE-8272.1.1 | GG1B2A | $^{14}C$-n-alkane | 205 | 2399 | 101 | 2302-2743 |
| | BE-8271.1.1 | GG1B3A | $^{14}C$-n-alkane | 303 | 3476 | 89 | 3556-3979 |
| | BE-7929.1.1 | GG1B3 | $^{14}C$-Bulk Sediment | 303 | 3517 | 111 | 3555-4091 |
| | BE-8270.1.1 | GG1B5A | $^{14}C$-n-alkane | 503 | 5789 | 109 | 6391-6804 |
| | BE-7928.1.1 | GG1B5 | $^{14}C$-Bulk Sediment | 503 | 5794 | 135 | 6305-6903 |
| | BE-8269.1.1 | GG1B6A | $^{14}C$-n-alkane | 602 | 6967 | 123 | 7589-8003 |
| | BE-7927.1.1 | GG1B6 | $^{14}C$-Bulk Sediment | 602 | 7320 | 144 | 7922-8404 |
| | BE-8268.1.1 | GG1B7A | $^{14}C$-n-alkane | 700 | 8267 | 137 | 8973-9535 |
| | BE-7926.1.1 | GG1B7 | $^{14}C$-Bulk Sediment | 700 | 8753 | 156 | 9516-10201 |
| | BE-8279.1.1 | 7L35.36 | $^{14}C$-Charcoal | 705 | 8753 | 162 | 9496-10206 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | BE-7925.1.1* | GG1B8 | $^{14}$C-Bulk Sediment | 794 | 10214 | 203 | 11267-12531 |
| | BE-8267.1.1* | GG1B8A | $^{14}$C-n-alkane | 794 | 9301 | 273 | 9740-11235 |
| | BE-8266.1.1 | GG1B9A | $^{14}$C-n-alkane | 898 | 9650 | 155 | 10545-11368 |
| | BE-7924.1.1 | GG1B9 | $^{14}$C-Bulk Sediment | 898 | 9706 | 175 | 10563-11640 |
| | BE-8276.1.1 | 9L55.56 | $^{14}$C-Charcoal | 925 | 10925 | 364 | 11823-13567 |
| Direct AMS | D-AMS 033974* | GG1B015 | $^{14}$C Bulk Sediment | 15 | 180 | 23 | 140-289 |
| | D-AMS 033975* | GG1B025 | | 25 | 310 | 23 | 304-456 |
| | D-AMS 033976* | GG1B045 | | 45 | 524 | 26 | 510-624 |
| | D-AMS 033977* | GG1B8C | | 821 | 10243 | 46 | 11773-12140 |
| | D-AMS 029493 | GG1B10 | | 998 | 11110 | 48 | 12828- 13082 |
| | D-AMS 029494 | GG1B11 | | 1108 | 11377 | 50 | 13102- 13313 |
| | D-AMS 029495 | GG1B12 | | 1218 | 12181 | 51 | 13906-14230 |
| | D-AMS 027899 | GG1B15 | | 1493 | 12977 | 53 | 15291-15740 |
| | D-AMS 029496 | GG1B15b | | 1528 | 12997 | 57 | 15304-15772 |
| | D-AMS 029497 | GG1B15c | | 1548 | 13294 | 59 | 15772-16193 |

* Not considered for the age depth model

Table S2. $^{210}$Pb concentrations in core BAL-GGU17-1A-1L taken from Lake Garba Guracha, Ethiopia

| Depth | Dry Mass | Pb-210 | | | | | | Cum Unsupported | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | | Supported | | Unsupp | | Pb-210 | |
| cm | g cm$^{-2}$ | Bq Kg$^{-1}$ | ± | Bq Kg$^{-1}$ | ± | Bq Kg$^{-1}$ | ± | Bq m$^{-2}$ | ± |
| 1.5 | 0.0661 | 1293.51 | 26.68 | 35.51 | 3.12 | 1258 | 26.86 | 855 | 44.6 |
| 4.5 | 0.4389 | 1008.99 | 31.88 | 36.56 | 4.04 | 972.43 | 32.13 | 4989.7 | 228.4 |
| 6.5 | 0.7642 | 709.4 | 29.51 | 34.71 | 4.45 | 674.69 | 29.84 | 7639.3 | 285.4 |
| 7.5 | 0.9188 | 665.94 | 29.15 | 26.44 | 3.94 | 639.5 | 29.42 | 8654.9 | 295.5 |
| 8.5 | 1.0774 | 537.72 | 27.79 | 34.6 | 4.2 | 503.12 | 28.11 | 9556.7 | 302.5 |
| 9.5 | 1.2495 | 377.38 | 15.46 | 41.52 | 2.92 | 335.86 | 15.73 | 10269 | 307.6 |
| 10.5 | 1.4216 | 373.38 | 26.47 | 33.25 | 4.18 | 340.13 | 26.8 | 10850.7 | 310.8 |
| 12.5 | 1.8091 | 291.27 | 15.35 | 42.58 | 2.84 | 248.69 | 15.61 | 11982.3 | 325.3 |
| 14.5 | 2.184 | 210.3 | 14.48 | 38.03 | 2.98 | 172.27 | 14.78 | 12762.6 | 332.8 |
| 16.5 | 2.5007 | 173.6 | 13.65 | 41.31 | 2.9 | 132.29 | 13.95 | 13242.1 | 337.2 |
| 18.5 | 2.8881 | 105.53 | 12.48 | 31.15 | 2.71 | 74.38 | 12.77 | 13631.7 | 341.5 |
| 20.5 | 3.3863 | 98.8 | 8.5 | 32.29 | 1.85 | 66.51 | 8.7 | 13982.3 | 346.4 |
| 22.5 | 3.8918 | 91.72 | 10.6 | 31.87 | 2.54 | 59.85 | 10.9 | 14301.4 | 349.9 |
| 24.5 | 4.3597 | 87.72 | 9.94 | 39.39 | 2.56 | 48.33 | 10.26 | 14553.5 | 353.9 |
| 26.5 | 4.7295 | 65.03 | 7.72 | 32.82 | 2.35 | 32.21 | 8.07 | 14700.4 | 356.1 |
| 28.5 | 5.017 | 83.85 | 8.88 | 39.53 | 2.24 | 44.32 | 9.16 | 14809.5 | 357 |
| 31.5 | 5.5316 | 59.6 | 9.1 | 33.97 | 2.15 | 25.63 | 9.35 | 14985.1 | 359.6 |
| 34.5 | 6.0403 | 72.58 | 6.75 | 39.99 | 1.71 | 32.59 | 6.96 | 15132.5 | 362.5 |
| 38.5 | 6.742 | 54.55 | 10.91 | 38.02 | 2.64 | 16.53 | 11.22 | 15298.5 | 366.7 |
| 42.5 | 7.4532 | 61.55 | 8.65 | 40.91 | 2.29 | 20.64 | 8.95 | 15430.2 | 374.5 |
| 46.5 | 8.1826 | 42.22 | 5.05 | 34.6 | 1.35 | 7.62 | 5.23 | 15525.5 | 379.2 |
| 51.5 | 9.1197 | 40.76 | 5.73 | 35.4 | 1.54 | 5.36 | 5.93 | 15600.3 | 382.3 |

Table S3. Artificial fallout radionuclide concentrations in core BAL-GGU17-1A-1L

| Depth | Cs-137 | | Am-241 | |
|---|---|---|---|---|
| cm | Bq $Kg^{-1}$ | ± | Bq $Kg^{-1}$ | ± |
| 1.5 | 50.26 | 2.46 | 0 | 0 |
| 4.5 | 89.11 | 4.22 | 0 | 0 |
| 6.5 | 113.64 | 4.86 | 0 | 0 |
| 7.5 | 140.75 | 5.08 | 2.82 | 1.7 |
| 8.5 | 102.63 | 4.67 | 0 | 0 |
| 9.5 | 42.19 | 2.16 | 0 | 0 |
| 10.5 | 38.21 | 3.22 | 0 | 0 |
| 12.5 | 21.79 | 1.86 | 0 | 0 |
| 14.5 | 21.3 | 1.87 | 0 | 0 |
| 16.5 | 11.01 | 1.37 | 0 | 0 |
| 18.5 | 8.5 | 1.36 | 0 | 0 |
| 20.5 | 8.87 | 0.92 | 0 | 0 |
| 22.5 | 9.52 | 1.34 | 0 | 0 |
| 24.5 | 7.28 | 1.24 | 0 | 0 |
| 26.5 | 3.75 | 1.21 | 0 | 0 |
| 28.5 | 4.49 | 1 | 0 | 0 |
| 31.5 | 2.68 | 0.99 | 0 | 0 |
| 34.5 | 3.41 | 0.71 | 0 | 0 |
| 38.5 | 3.01 | 1.14 | 0 | 0 |
| 42.5 | 0 | 0 | 0 | 0 |
| 46.5 | 0 | 0 | 0 | 0 |
| 51.5 | 0 | 0 | 0 | 0 |

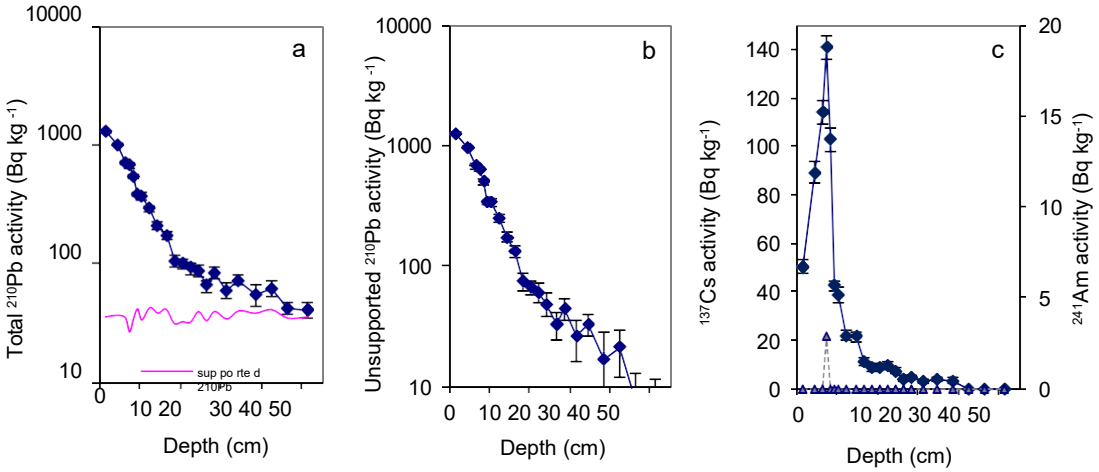


Figure S4. Fallout radionuclide concentrations in core BAL-GGU17-1A-1L taken from Lake Garba Guracha, Ethiopia, showing (a) total $^{210}$Pb, (b) unsupported $^{210}$Pb, and (c) $^{137}$Cs and $^{241}$Am concentrations versus depth

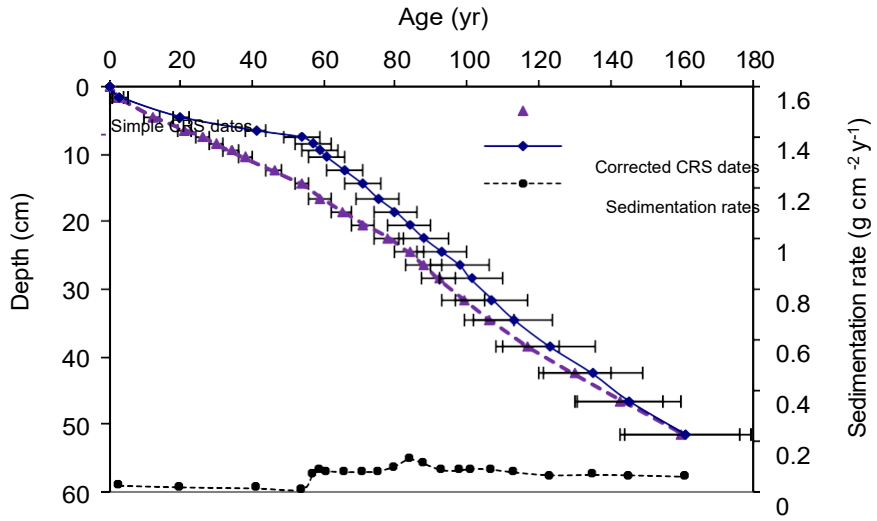


Figure S5. Radiometric chronology of core BAL-GGU17-1A-1L taken from Lake Garba Guracha, Ethiopia, showing the CRS model $^{210}$Pb dates and sedimentation rates

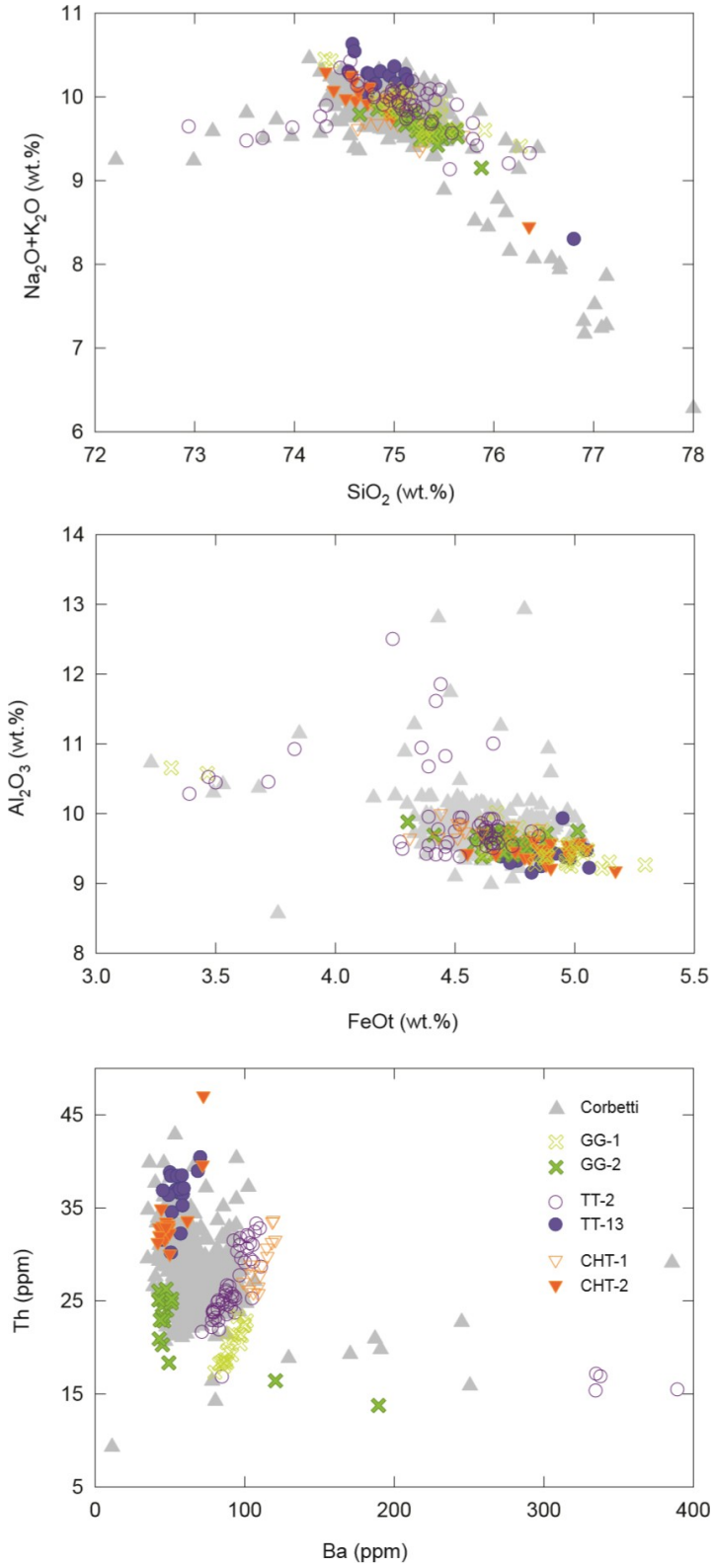


Fig S6. Bi-plots showing the concentrations of major and trace elements in glass shards within the Garba Gurache tephras. The compositions of rocks erupted from the Corbetti is shown in grey for comparison, alongside the composition tephra deposits from two of its largest Holocene eruptions, found at lakes Tilo and Chamo in the central Main Ethiopian Rift. Concentrations of Ba and Th clearly differentiate the tephras. The similarity in Ba/Th ratios suggests that GG-1 correlates to the Tilo tephra TT-2 and CHT-1 at Chamo, whilst GG-2 correlates to TT-13 and CHT-2